PATENT SPECIFICATION
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(54) DEVICE FOR DETECTING SUBMERGED BODIES BY MEANS OF EXTREMELY LOW FREQUENCY RADIO WAVES

(71) We, SUD-AVIATION Société Nationale de Constructions Aéronautiques, a French Body Corporate, residing at 37, Boulevard de Montmorency, Paris, (Seine), France, do hereby declare the invention for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statements:-

The present invention relates to a device for detecting submerged bodies by means of extremely low frequency (ELF) radio waves, examples being metallic bodies such as submarines.

According to this invention, a system for detecting submerged bodies by means of extremely low frequency radio waves is characterised in that it comprises one or more extremely-low-frequency-wave transmitting stations, and a multiplicity of receiving stations spaced from one another, each transmitting station consisting of means for generating waves at an extremely low frequency ranging from 1 to 100 c/s and means for radiating said waves through the air and through the sea water, and each receiving station comprising a first device orientated towards the corresponding transmitting station for receiving the ELF waves transmitted directly from the transmitting station through the air, a second device for receiving directionally the ELF echo waves produced by the waves which are transmitted through the sea water after reflection off a submerged body, an apparatus for measuring the phase-shift between the directly transmitted and echo waves, and means for determining the bearing angle between the direction for which the reception of the echo waves is maximum and a stationary direction which is smaller for all the receiving stations, in order, on the one hand, to compute the depth of said submerged body from the corresponding measured phase-shifts and, on the other hand, to determine by the cross-bearing method the geographical position of said obstacle by utilising the corresponding determined bearing angles whereby said apparatus may be used for locating a submerged body utilising the signals at the receiving stations for which the lines joining said stations to the transmitter and to the detected body from an inclined angle comprised between 60° and 120°. At the station where the direction of the object to be detected lies within these limits, the directly transmitted signal can be received by directional receiving means with only a very small component of echo signal so that the phase of the directly transmitted signal is available as a reference for determining the phase shift of the echo signal; this is necessary to compute the depth of the object without error.

Preferably several different transmission frequencies are respectively used at several transmitting stations and differently phase-displaced signals are respectively received at several receiving stations, in such a way that the transmitting stations may be placed in proximity to one another without causing mutual interference.

Advantageously each receiving station is equipped with two directional receiving antenna loops, respectively orientated towards the corresponding transmitting station and towards the detected submerged body and both connected to a depthwise-calibrated phasemeter by electrical circuit means which render negligible the electromotive force induced by the transmitting station in the loop antenna orientated towards the submerged body when the lines which join said receiving station to said transmitting station and to said body, respectively, form an included angle comprised between 60° and 120°.

The transmission antenna of each transmitting station is preferably of the type described in British Patent Application No. 18473/61 (Serial No. 1253023) filed by the applicants on

May 19, 1961 in respect of "Device for radiating megametric radio waves".

The system of the present invention may be used for detecting submerged bodies as hereinbefore described, and in particular for the detection of underwater objects or bodies in motion, such as submarines, torpedoes or minefields.

The description which follows with reference to the accompanying drawings given by way of example and not of limitation will give a clear understanding of how the invention may be performed and will bring out yet further particularities thereof.

In the drawings, *Figure 1* is an explanatory diagram showing the detection of a submerged object by the use of ELF waves, in accordance with the invention;

Figure 2 is a schematic diagram showing a detection system comprising a land transmitting station and receiving stations, in accordance with the invention;

Figure 3 is a schematic diagram showing a detection system comprising a seagoing transmitting station and receiving stations, in accordance with the invention;

Figure 4 is an electrical circuit diagram of a transmitter for use in a detection system such as that of Figures 2 or 3;

Figure 5a is a graph in which discharges from the transmitter of Figure 4 are plotted against voltage;

Figure 5b shows the voltages across the terminals of the transformer associated with the transmitter in Figure 4;

Figure 6 shows trains of waves produced by the modulator of the transmitter in Figure 4;

Figure 7 is a diagrammatic illustration of a receiver for use in a detection system such as that of Figure 2 or Figure 3;

Figure 8 is a graphical diagram showing the phase displacement between the ELF wave emitted by the transmitter in Figure 4 and the wave reflected by the obstacle and received by the receiver in Figure 7; and

Figure 9 schematically represents a plurality of detection systems with transmitting stations operating at different frequencies.

The detection system of the present invention uses extremely low frequency radio waves simultaneously radiated through the air and through the sea water. Preferably, but not limitatively, the antenna for emitting such waves is of the type described in the British Patent Application No. 18473/61 (Serial No. 1253023) filed by Applicants on May 19, 1961.

As explained in the above-mentioned British Patent Application, extremely low frequency electromagnetic waves cannot be propagated over large distances above ground unless the "electrical field" vector of the waves is vertical. In fact however, and as shown in Figure 1 of the accompanying drawings, the electrical field vector E of such extremely low frequency waves is always slightly inclined towards the direction F of propagation above the surface of the earth while its magnetic field vector H is substantially parallel to the earth. This vector E may be resolved into a horizontal component Ex and a vertical component Ez. The type of wave which generates this electrical field E is known as a Zenneck wave. The vertical component Ez of this electrical field E, travels great distances in the direction F above ground and becomes attenuated as the distance increases; this component enables reception stations located very far from the transmitting station to be reached. The horizontal component Ex of this electrical field E and the magnetic field H perpendicular thereof will travel perpendicularly to the surface of the earth and, if the wave be travelling over the sea, will be propagated downwardly to a body O even if submerged at great depth. The lower the wave frequency, the less is the attenuation. In Figure 1 the amplitudes at different depths of a signal corresponding to the horizontal component Ex of the electrical field E are represented, for depths of z_1, z_2 and z_3, by the vectors E_1x, E_2x and E_3x.

In addition, the speed of propagation of the horizontal component Ex towards the sea-bed is much lower than the speed of propagation of the electrical vector E through air, the latter speed of propagation being the same as that of light in air. This speed of propagation downwardly through the sea depends upon the wave frequency, and is equal to 16,000 metres per second for a frequency of 100 c/s and to 1,600 metres per second for a frequency of 1 cycle per second. Thus, if the echo produced by the field Ex off the submerged body O at a depth of 400 metres to be measured, the time taken for the vector Ex to travel there and back when emitted at a frequency of 1 cycle per second is equal to that of half a period, namely half a second. It is precisely this lapse of time which, in accordance with the present invention using extremely low frequency waves or ELF waves, is measured accurately by means of a phasemeter with a view to determining the distance d of the uppermost part of the submerged body O from the surface of the sea, in accordance with the formula

$$T = \frac{2.d}{V_f} \tag{1}$$

where T is the out-and-back time taken by the propagation of vector Ex and V$_f$ the speed of propagation of that vector through the sea water at a frequency f.

A point analogous to the point A of Figure 1 always exists on the surface of the sea in vertical alignment with submerged body O, due to the existence of electrical fields E produced, as is well known to radio engineers, by the semi-circular lines of force of the electrical field forming part of an emitted ELF wave.

The vector E$'_x$ representing the field reflected by the submerged body O (Figure 1) is attenuated as it travels towards the surface of the sea, where it gives rise to an electrical vector analogous to E and which appears after a time ΔT, at the instant when the vector E occupies a position E$'$ after covering a distance ΔL, exhibiting a phase-shift $\Delta\theta$ in relation to the directly transmitted electrical vector E. Owing to the fact that the time of propagation in the air is negligible since the speed of propagation in the air is equal to that of light, this phase-shift $\Delta\theta$ is only related to the time of vertical propagation of the wave in the sea water, i.e. only related to the depth d of the submerged obstacle O to the wavelength λ_m, for the frequency used. This phase shift is given by the formula

$$\Delta\theta = 2\pi \frac{2.d}{\lambda_m} \tag{2}$$

If f is the wave frequency and T the period, said formula (2) may be transformed by using the fundamental relation :

$$\lambda_m = V_f T = \frac{V_f}{f} \tag{}$$

whence

$$\Delta\theta = 2\pi \ f \frac{2 \ d}{V_f} \tag{3}$$

where $\frac{2d}{V_f}$ represents the time.

In the region surrounding a vertical line passing through the submerged body, the signal reflected by the latter gives rise, firstly, to an induction field which decreases as $1/D^3$, where D is the distance between the point where the measurement is made and the point through which the vertical line through the submerged body cuts through the surface of the sea, and, secondly, to a propagation field which decreases as $1/D$ and which can consequently travel great distances.

The detection system of the present invention makes use of at least one transmitting station radiating ELF signals and a number of spaced receiving stations which receive the signals transmitted directly from the transmitting station and also the above described propagation field signals reflected from a submerged body. One such detection system illustrated in Figure 2 comprises a transmitting station 1, having an antenna 2 adapted to radiate ELF waves through the air and through the sea water, together with a multiplicity of receiving stations 3a, 3b, etc. Each of these receiving stations is equipped with a highly sensitive directional antenna loop 4a, 4b, etc., preferably of the type with ferrite cores, the operating principle of which is well known per se. Such antenna loops enable the direction from which the echo off the submerged body O is coming to be ascertained, provided care is taken to orientate the axis of said loop perpendicularly to the direction of the submerged body in order to obtain maximum echo amplitude.

Thus, in the case of Figure 2, the antenna loop 4a of receiving station 3a, directed at a bearing angle θ_1 relative to true North gives an azimuth of θ'_1 in respect of line 3a-O. Similarly, the loop 4b of station 3b directed at a bearing angle θ_2 relative to true North gives an azimuth of θ'_2 for the line 3b-O. If now the positions of the receiving stations and transmitter station, on the one hand, and the azimuths θ'_1, θ'_2, etc., obtained for each of these positions, on the other, be plotted on a graph drawn to scale, then the location of the submerged body O can be obtained by the cross-bearing method by utilising said bearing angles. However, and as will be explained hereinbelow, the data furnished by the receiving stations 3a and 3b for phase-shift and bearing angle can be used without error only if the signal directly transmitted through the air to the receiver can be received without any appreciable component of echo signal so that it can be used as a phase reference standard

and for cancelling the directly received signal component from a signal containing both such a component and an echo signal; for practical purposes, this condition is fulfilled if the lines joining the receiving stations to the transmitter 1 and those joining the receiving stations to the submerged body, to be detected form included angles α'_1, α'_2 .... comprised between 60° and 120°. To overcome this drawback, any desired number of receiving stations of the same type may be disposed to form a detection system in conjunction with a common transmitting station. In this manner, if such an angular condition is not fulfilled for one receiving station, it may be fulfilled for another.

In the example illustrated in Figure 2, the detection system comprises a group of stations arranged along a coastline 5. However, the detection system could equally well be disposed on the high seas, with the transmitting station 1m installed on a ship 6 and the receiving stations 3am and 3bm on ships 7a and 7b. It will then suffice for these three ships 6, 7a and 7b to know their respective positions accurately for the submerged obstacle O also to be located accurately relative to one of these ships taken as a datum.

The ferrite-type antenna loops of ships 7a and 7b will give the azimuths θ''_1, θ''_2 of the lines 3am-O and 3bm-O relative to true North, and these azimuths can be used providing the angles α''_1 and α''_2 are comprised between 60° and 120°. The antenna loops of land stations 3a and 3b and of ship-borne stations 3am and 3bm are associated with phasemeters which will indicate the same depth in respect of the submerged body O for all these receiving stations jointly operating as a detection group in conjunction with a common transmitting station.

The transmitting station, or transmitter, consists basically of a device for generating high power energy at the wavelength to be used and of a radiating system which enables part of the energy applied to it to be radiated through the air and through the sea water on the extremely low frequencies employed yet which involves no excessive size penalty.

The radiating system may conveniently be one of the type described in the aforementioned British Patent application. This comprises two metal floats distant from each other by several kilometres and supporting fully-immersed electrodes of large size, one of which is connected by an insulated surface cable to the secondary winding of a transformer the primary winding of which is connected to a source of current generating in said secondary winding a difference in potential across said electrodes which alternates therebetween at the extremely low frequency to be used, ranging from 1 c/s to 100 c/s, the secondary winding of said transformer being connected to the other electrode by means of an insulated cable immersed at great depth or lying on the sea-bed, the said primary and secondary windings being designed to fully match the load represented by the impedance across said electrodes and said source of current.

The high power energy generator may take the form of a high power a.c. generator or of a conventional very-low-frequency valve oscillator, or alternatively of a high-power, adjustable-frequency modulator of the spark-gap type.

In Figure 4 there is shown one embodiment of transmitter using a high power, very-low adjustable-frequency modulator of the spark-gap type. This transmitter comprises a source 8 of very high d.c. voltage, say 50 to 100 kV, supplied by the mains system 9 and capable of delivering an average current intensity of several hundred amperes. Said source comprises rectifier elements of known type which are not illustrated for the sake of clarity.

Through a switch 10, which is closed when the transmitter is utilised, said source 8 continuously charges two large and very carefully insulated capacitors C_1 and C_2 via two resistors R_1 and R_2. These capacitors have one of their terminals connected to ball-type spark-gaps 11a and 11b and their other terminals to a push-pull type transformer 12. The spark-gap 11a used to discharge the capacitor C_1 comprises two balls 13a and 14a while the spark-gap 11b used to discharge the capacitor C_2 comprises two balls 13b and 14b. Balls 14a and 14b contain auxiliary spark-gaps 15a and 15b acting as exciters which, through the action of minute, very-short-duration arcs produced by short pulses delivered by an electronic control device 16, enable powerful arcs to be triggered across the balls 13a, 14a and the balls 13b, 14b. The discharges of said capacitors C_1 and C_2 are alternated in order to generate in the primary 17 of transformer 12 an a.c. voltage the half-period of which is furnished by the time interval separating successive sparks produced in the auxiliary spark-gaps or exciters 15a and 15b. The current across the respective pairs of balls of each of spark gaps 11a and 11b is limited only by the electromotive force set up across the terminals of primary winding 17 of transformer 12. Capacitors C_3 and C_4 placed in parallel with each half-winding of said primary 17 tune the frequency of transformer 12 to the fundamental frequency obtained. The secondary winding 18 of transformer 12 feeds the antenna illustrated diagrammatically at 19 and which as previously been described.

The pulses delivered by the electronic device 16 (a conventional device of a type familiar in transmitters utilising spark-gap-type modulators) can be spaced at will and be furthermore grouped together in pulse trains in order to provide trains of pulses of high

power and short duration, comprising, for example, three or four fundamental oscillations. Figure 5a illustrates, as an example, the generation of a pulse train comprising two full cycles. Pulses 1 and 3 trigger one pair of spark gaps, and pulses 2 and 4 trigger the other pair. The discharges produced by capacitors C_1 and C_2 in each half-winding of the primary 17 of transformer 12 are of the shape shown in Figure 5a. The tuned primary winding of said transformer enables a voltage to be obtained, a graphical illustration of which is given in Figure 5b.

A modulator of the type illustrated in Figure 4 enables considerable peak power capable of reaching several thousand megawatts to be obtained. Figure 6 shows successive pulse trains of three full cycles each furnished by the transmitter in Figure 4. These trains have a duration t and are separated from one another by time intervals T which may be as much as one minute in cases where it is desired to operate at very large peak powers with a medium-power, high-voltage supply system. Thus, for a frequency of 10 cycles per second for example, the pulse trains would have a duration of 0.3 second and the mean power delivered to the secondary winding of the adapter-transformer would be 5,000 kW for a peak power of 1,000 MW.

Figure 7 illustrates a receiving station which may be of the land, sea or airborne type. This receiving station may be used as the station 3a or 3b of Figure 2 or the station 3am or 3bm of Figure 3. It comprises a main directional loop 4 which may be orientated in any direction about a supporting spindle 20. If this loop 4 is obliquely orientated with respect to the transmitting station and to the submerged body it receives simultaneously signals both from the transmitting station and from the submerged body, the echo signal being delayed slightly and thereby shifted in phase with respect to the directly received signal as previously described. A second auxiliary directional loop 21 rotatably mounted on a supporting spindle 22 is orientated towards the transmitter. If the preceding angular condition is fulfilled, i.e. the lines joining the receiver to the transmitter and to the submerged body form an included angle comprised between 60° and 120°, the submerged body forms with said orientated auxiliary loop 21 an angle neighbouring 90°. Therefore, the echo signals from the submerged body received at said loop 21 come from a direction near the minimum of the directional receiving pattern of the loop. The echo signals are attenuated due to the passage through the water and generate in said loop a negligible electro-motive force. The signals in the loop are thus substantially solely the signals directly radiated through the air from the transmitter. The purpose of this loop 21 is to define the phase of these transmitted signals. For practical purposes, provided the lines joining the receiver to the transmitter and the submerged body form an included angle between 60° and 120°, the signal in the loop will be for the most part coming directly from the transmitter and can be considered as being representative of the phase of the transmitted signals. These signals in the loop 21 form the phase reference standard used in the measurement of the depth d of the submerged body which is done by isolating the echo signal and comparing its phase with that of the transmitted signal.

To this end, the auxiliary directional loop 21 feeds into an amplifier 23 which supplies an adjustable phase-shifter 24 and a pulse generator 25 of any known type. Said phase-shifter 24 feeds into the field coil 26 of a variometer 27, the core 28 carrying said coil being rigidly connected to a spindle 29. Said spindle 29 carries a sprocket wheel 30 coupled, via a chain 31, to a sprocket wheel 32 of identical diameter carried by the spindle 22 of the auxiliary directional loop 21. Thus, when this auxiliary directional loop 21 is turned, the axis of the loop 21 and that of the field coil 26 of the variometer remain rigorously parallel.

The second or receiving coil 33 of variometer 27 has its core 34 rigidly connected to a spindle 35 upon which is mounted a sprocket wheel 36 connected, by a chain 37, to a further sprocket wheel 38 of identical diameter carried by the spindle 20 of the main antenna loop 4. Thus, during turning of said loop 4, the axis of the loop 4 and that of coil 33 remain rigorously parallel.

The phase-shifter 24 is conventionally adjusted so that the induction field in the coil 26 is of exactly opposite phase to that of the electrical field produced by the transmitter at the transmitting station. Thus, the electro-motive force induced in the coil 33 is of exactly opposite phase to that of the electro-motive force which is generated in the main loop 4 in response to the field emanating from the transmitter. When said main loop 4 is orientated in a search for maximum echo amplitude, the electro-motive force induced therein in response to the transmitter field remains rigorously proportional to the electro-motive force induced in coil 33 of the variometer. If, in addition, the receiving station is in a position such that the lines joining it to the transmitter and to the submerged object form an included angle comprises between 60° and 120°, then the electro-motive force induced in the auxiliary loop 21 in response to the reflected field produced by the echo is negligible. By adjusting the amplitude of the electro-motive force furnished by coil 33, cancellation may be obtained, in an adder 40 connected to said coil 33, of the electro-motive forces induced by the transmitter field

in the main loop 4 and the said coil 33, respectively, regardless of the orientation of the main loop.

Considering the signals transmitted directly from the transmitting station, the amplitude of the signals which are received by the main loop 4 will have its maximum value when said loop is orientated towards said transmitting station. If the maximum amplitude after amplification by amplifier 41 is say A, and if loop 4 is then rotated through an angle ψ the amplitude of the signals from said amplifier becomes A cos ψ.

Assuming the main loop 4 and the auxiliary loop 21 are orientated towards the transmitting station, so that the axis of the receiving coil 33 coincides with that of the field coil 26 of variometer 27, the directly transmitted signals generate in the coil 33 an electromotive force having an amplitude - B.

The field coil 26 remaining stationary, a simultaneous rotation of loop 4 and coil 33 through the same angle ψ gives at the output of amplifier 41 a signal the amplitude of which is equal to A cos ψ and at the output of coil 33 a signal having an amplitude equal to - B cos ψ. These two signals are transmitted to an adder 40 which furnishes signals the amplitude of which is equal to :

$$A \cos \psi - B \cos \psi.$$

By the adjustment of the gain of amplifier 41 in any known manner, it is possible to obtain A = B. In this way the signals issued from adder 40 will have an amplitude equal to zero whatever ψ may be, since

$$A \cos \psi - B \cos \psi = O \qquad (4)$$

If the gain of the amplifier is adjusted in this manner, the component in the output of the amplifier 41 due to the directly transmitted signal will be cancelled in the adder 40 by the component from the coil 33, of the signal picked up by the loop 21. For exact cancellation of the directly transmitted signal to occur when an echo signal is present, it is necessary that the output from the coil 33 and hence the output from loop 21 should be substantially wholly dependent on the directly transmitted signal without any appreciable component of echo signal. Thus where for a receiving station exact cancellation does not occur when the rotating loop 4 of said station passes in alignment with the transmitting station, echo signal is present from a submerged body situated, in other words the lines joining said receiving station to the transmitting station and to the submerged body form an included angle either less than 60° or greater than 120°. The electro-motive force thus remaining in adder 40 oppose the electromotive force generated by the echo signals received by the main loop 4 and transmitted to said adder. This prevents the receiving station from accurately locating said body.

When echo, obtained by the reflection off the submerged body of the horizontal component of the electrical field of the ELF megametric waves from the transmitter, is received in the main loop 4, the signal is immediately amplified by an amplifier 41 and then applied to the adder 40, and this signal finds no opposing electro-motive force in said adder, provided that the previously specified conditions of angular spacing between the receiver-to-transmitter and receiver-to-body lines are met. The main loop 4 can therefore be orientated at a bearing angle θ in order that it shall receive echo signals of maximum amplitude. Amplifier 41 is further connected to an oscillograph 42 providing visualisation of the echo and to the loop-orientating-device enabling maximum amplitude to be obtained. The signal from adder 40 operates a pulse generator 43, an integrator 44 and, ultimately, a phasemeter 45 which provides a direct reading of the depth d at which the body is submerged. The amplifiers 23 and 41, the phase-shifter 24, the adder 40, the oscillograph 42, the pulse generators 25 and 43, the integrator 44 and the phasemeter 45 are supplied with current in any conventional manner. Being entirely conventional in every respect, these various pieces of apparatus will not be described in detail.

Figure 8 provides a clear understanding of the manner of operation for the receiving device shown in Figure 7. The transmitted signal e shown in this figure has a duration t and is assumed to comprise three full cycles. By means of the pulse generator 25, pulses 1, 3 5 are obtained which are initiated exactly at the instants of passage across the zero-line of the sinusoidal signal of duration t. The pulse generator 43, which receives obstacle-reflected trains of phase-shifted waves, represented by the sinusoidal signal o in Figure 8, enables pulses 2, 4, 6 to be initiated precisely at the points of crossing of the zero-line by the sinusoidal signal o of the pulse train representing the signal reflected by the submerged body. The pulses 2, 4 and 6 are phase-shifted in relating to pulses 1, 3, 5 by a quantity Δθ defined hereinabove with reference to formulae (2) and (3). The pulses 1, 3, 5, produced by pulse generator 25 and 2, 4, 6 produced by pulse generator 43 are applied to the integrator 44, in which the phase-shifts Δθ are converted into direct current by conventional methods

well known per se, and subsequently supplied to the phasemeter 45 which gives a direct reading of the depth d of the submerged body.

It is to be clearly understood that many modifications suggested by technology or practical considerations may be made to the present invention without departing from its scope as defined in the appended claims. As an example, the directional antenna loops may be of any well-known type, but preferably of the type using ferrites. Similarly, the mechanical drive between individual directional loops and the corresponding variometer coil may be executed in a manner different from that shown in Figure 7, any known method being suitable provided rigorous parallelism is ensured between the axis of each loop and that of the variometer coil. Lastly, it is possible to use a plurality of transmitters $1x$, $1y$, $1z$,.....(Figure 9) having submerged antennae and operating at different frequencies X c/s, Y c/s, Z c/s,... In this manner signals variously phase-displaced may be received without mutual interference between the transmitters at several receiving stations $3d$, $3e$, $3f$, $3g$ $3hm$,....

WHAT WE CLAIM IS:

1. A system for detecting submerged bodies by means of extremely low frequency radio waves characterised in that it comprises one or more extremely-low-frequency-wave transmitting stations, and a plurality of receiving stations spaced from one another, each transmitting station consisting of means for generating waves at an extremely low frequency ranging from 1 to 100 c/s and means for radiating said waves through the air and through the sea water, and each receivig station comprising a first device orientated towards the corresponding transmitting station for receiving the ELF waves transmitted directly from the transmitting station through the air, a second device for receiving directionally the ELF echo waves produced by the waves which are transmitted through the sea water after reflection off a submerged body, an apparatus for measuring the phase-shift between the directly transmitted and echo waves, and means for determining the bearing angle between the direction for which the reception of the echo waves is maximum and a stationary direction which is similar for all the receiving stations, in order, on the one hand, to compute the depth of said submerged body from the corresponding measured phase-shifts and, on the other hand, to determine by the cross-bearing method the geographical position of said obstacle by utilising the corresponding determined bearing angles, whereby said apparatus may be used for locating a submerged body utilising the signal at the receiving stations for which the lines joining said stations to the transmitter and to the detected body form an included angle comprised between 60° and 120°.

2. A detection system according to claim 1, characterised by the fact that several different frequencies are respectively used for transmission at the transmitting stations and that differently phase-shifted signals are respectively received at the receiving stations.

3. A detection system according to either claim 1 or claimm 2 characterised by the fact that each receiving station is equipped with two directional receiving antenna loops respectively orientated towards the corresponding transmitting station and towards the detected submerged body and both connected to a depthwise-calibrated phasemeter by electrical circuit means which render negligible the electro-motive force induced by the transmitting station in the antenna loop orientated towards the submerged body when the lines which join said receiving station to said transmitting station and to said body, respectively, form an included angle comprised between 60° and 120°.

4. A detection system according to any of the preceding claims characterised by the fact that each transmitting station is along a coastline or at sea, while the receiving stations are on land, at sea, or in the air.

5. A detection system according to any of the preceding claims characterised by the fact that the device for generating ELF waves is a high power a.c. generator or a very-low-frequency conventional valve oscillator, or, alternatively, an adjustable very-low-frequency modulator with high-power spark-gaps.

6. A detection system according to claim 5 and employing a spark-gap modulator comprising two large and insulated main capacitors fed through resistors from a very-high-voltage d.c. source supplying current of very great intensity, said capacitors discharging into ball-type spark-gaps having auxiliary spark-gaps governed by a control-pulse-generating electronic device, and being connected to the primary of a push-pull-connected transformer the half-windings of which are turned by adjustable capacitors connected in parallel to the fundamental frequency obtained, the secondary of said transformer being connected to the radiating system.

7. A detection system according to any one of claims 1 - 6, characterised by the fact that the radiating system comprises two metal floats distant from each other by several kilometres and supporting fully-immersed electrodes of large size, one of which is connected by an insulated surface cable to the secondary winding of a transformer the primary winding of which is connected to a source of current generating in said secondary

winding a difference in potential across said electrodes which alternates therebetween at the extremely low frequency to be used, ranging from 1 c/s to 100 c/s, the secondary winding of said transformer being connected to the other electrode through the medium of an insulated cable immersed at great depth or lying on the sea-bed, the said primary and secondary windings being designed to fully match the load represented by the impedance across said electrode and said source of current.

8. A detection system according to claim 3, characterised by the fact that the electrical circuit means between the two directional receiving antenna loops of each receiving station, on the one hand, and the corresponding phasemeter on the other, comprises a first amplifier connected to the transmitter-orientated antenna loop and supplying a phase-shifter connected to one of the coils of a variometer which is itself connected to said transmitter-orientated antenna loop so that its axis remains rigorously parallel to that of said loop, said phase-shifter being adjusted so that the induction field in said variometer coil is of exactly opposite phase to that of the electrical field produced by the transmitter at the transmitting station, the second variometer coil which is mechanically coupled to the submerged body orientated antenna loop to ensure rigorous parallelism between their respective axes being further coupled to an adder fed by a second amplifier connected to said submerged body orientated antenna loop, said first amplifier and said adder supplying two pulse generators which feed into an integrator wherein the phase shifts between the signals emitted by said pulse generators are converted into direct current for the supply of said phasemeter the reading of which may be taken as correct provided that the included angle between the receiver-to-transmitter and receiver-to-submerged body lines is comprised between 60° and 120°.

9. A detection system according to claim 8, characterised by the fact that the second amplifier feeds an oscillograph providing a visual display of the echo signal amplitude.

10. A detection system according to claim 3, or any claim appendant thereto characterised by the fact that the directional receiving antenna loops are ferrite-type antenna loops.

11. A detection system according to any one of claims 1 - 10, characterised by the fact that it is used for detecting underwater obstacles or bodies in motion, such as submarines, torpedoes or minefields.

12. A detection system substantially as hereinbefore described with reference to and as illustrated in Figure 2 of the accompanying drawings.

13. A detection system substantially as hereinbefore described with reference to and as illustrated in Figure 3 of the accompanying drawings.

14. A detection system as claimed in claim 1 and embodying a transmitting station substantially as hereinbefore described with reference to and as illustrated in Figure 4 of the accompanying drawings.

15. A detection system as claimed in claim 1 and embodying a receiver substantially as hereinbefore described with reference to and as illustrated in Figure 7 of the accompanying drawings.

BOULT, WADE & TENNANT,
Chartered Patent Agents,
111-112, Hatton Garden,
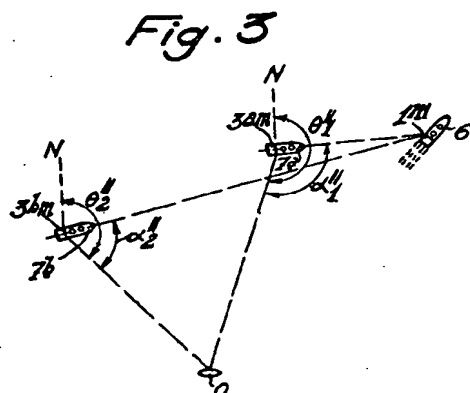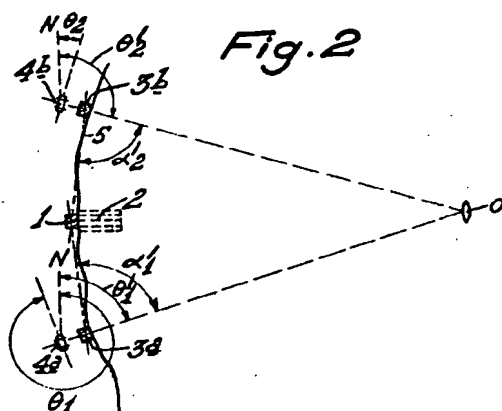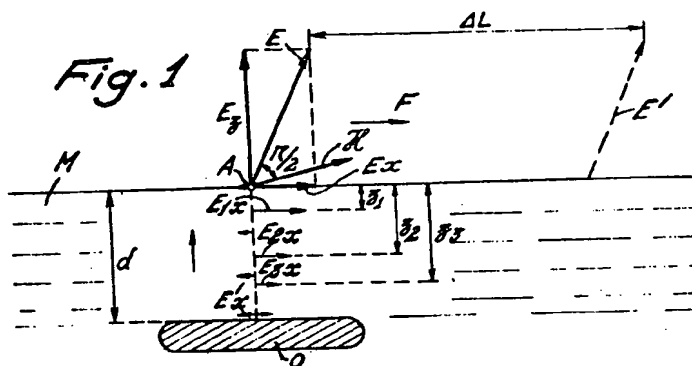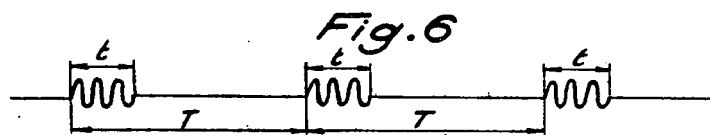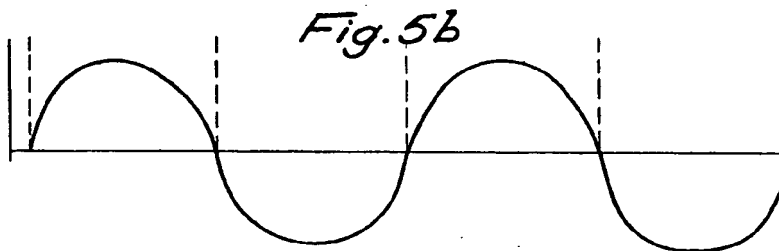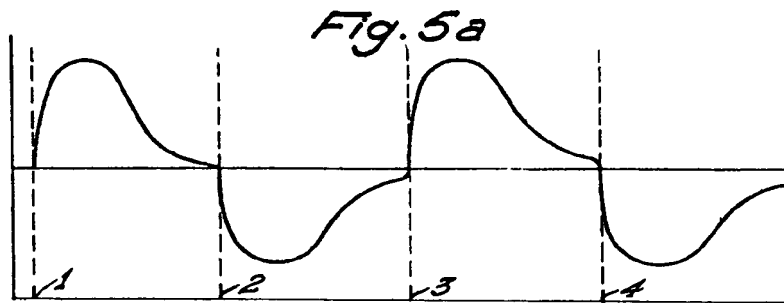London, E.C.1.,
Agents for the Applicants.

1590944   COMPLETE SPECIFICATION

3 SHEETS   This drawing is a reproduction of
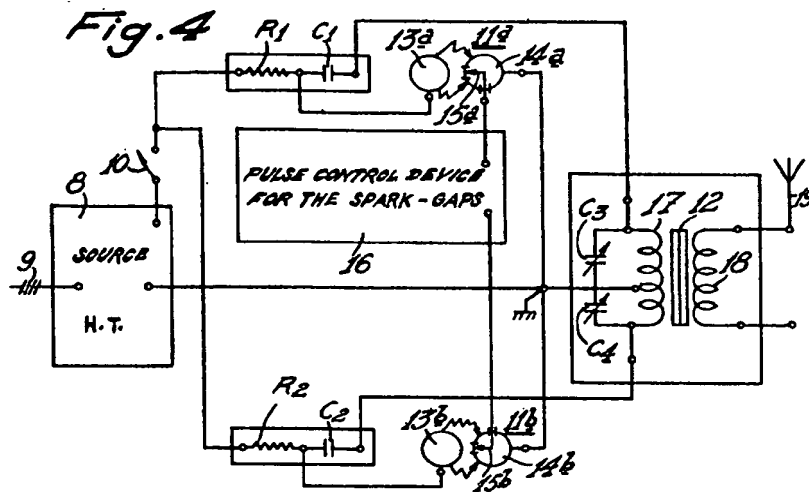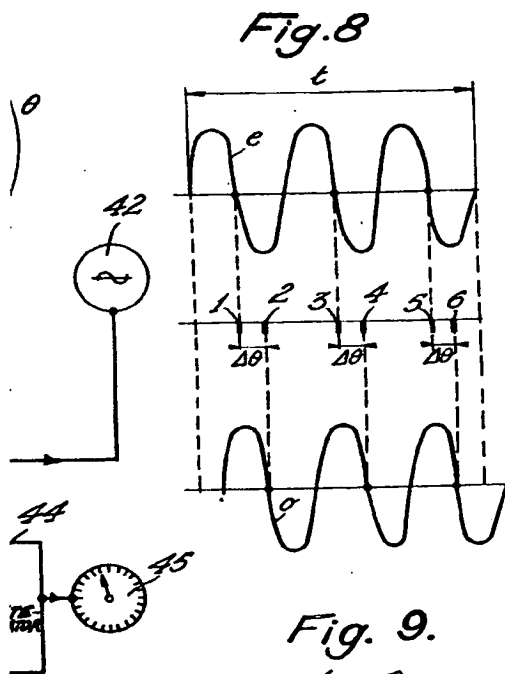the Original on a reduced scale
Sheet 1

Fig.1

Fig.2

Fig.3

Fig.4

PULSE CONTROL DEVICE
FOR THE SPARK - GAPS

16

SOURCE

H.T.

R1   C1

R2   C2

Fig.5a

Fig.5b

Fig.6

Fig.7

AMPLIFIER

PHASE SHIFTER

ADDER

AMPLI...

PULSE GENERATOR

PULSE GENERATOR

Fig.8

Fig. 9.